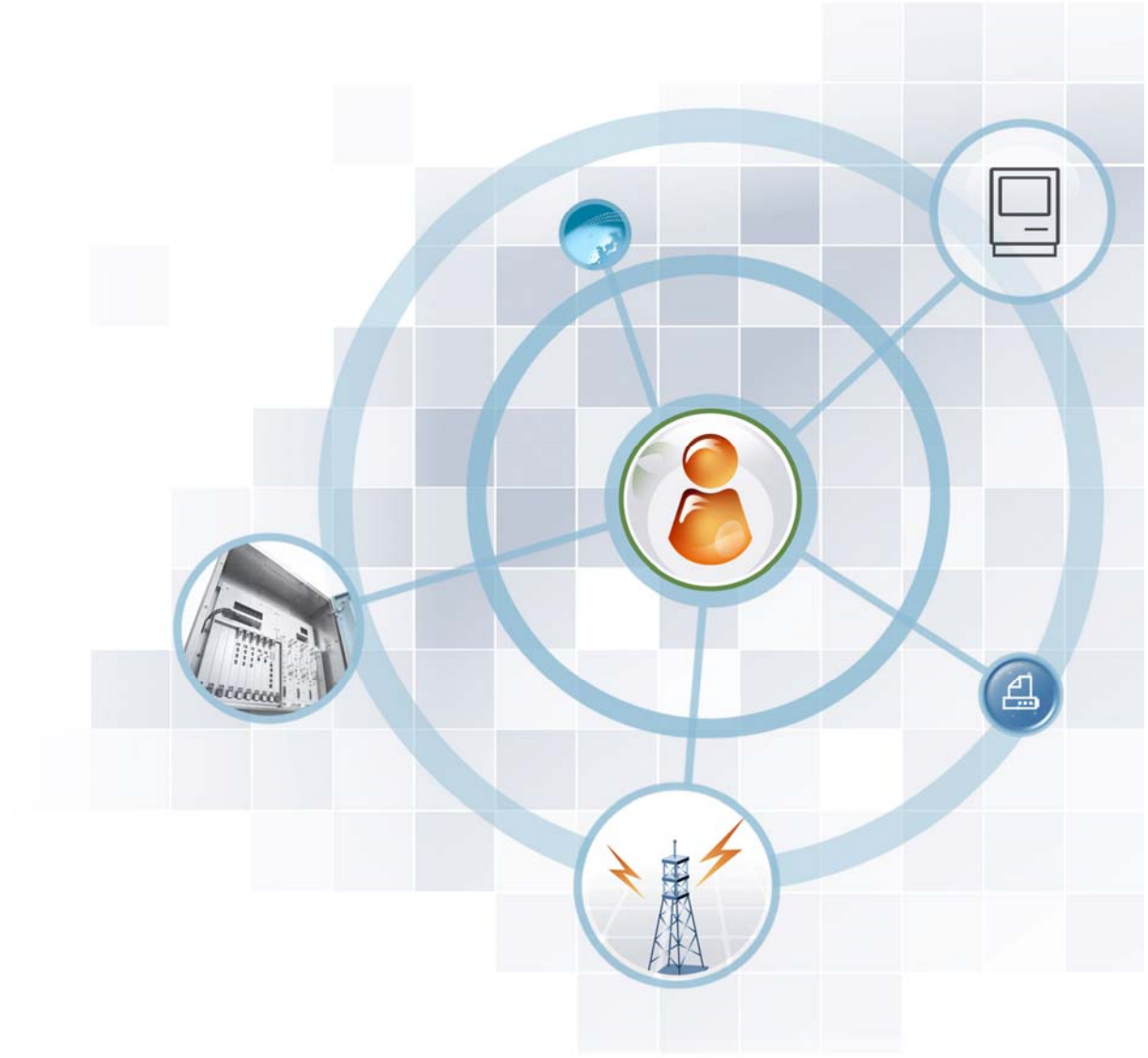
LTE eSmallCell

# System Description



SAMSUNG ELECTRONICS

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# INTRODUCTION

## Purpose

This description describes the characteristics, features and structure of the enterprise SmallCell (eSmallCell), an LTE eNB.

## Document Content and Organization

This manual consists of four Chapters and a list of Abbreviations.

### CHAPTER 1. Network Architecture

- eSmallCell Network Configuration
- Interface Specifications

### CHAPTER 2. System Hardware Structure

- Introduction to eSmallCell
- eSmallCell (L7IA)
- External Interface
- Cables and Antennas
- Mount Bracket
- Specifications

### CHAPTER 3. System Software Structure

- Software Structure
- Data Traffic Flow
- Network Sync Flow
- Alarm Signal Flow
- Loading Flow
- Operation and Maintenance Message Flow

### CHAPTER 4. System Functions

- Physical Layer Processing
- Interference Mitigation
- Call Processing Function
- Closed Subscriber Groups (CSG) Function
- IP Processing
- Over the Air Receiver (OTAR) based GPS Locking Assistance Function
- Plug and Play Function
- Self Organizing Network (SON)
- Security
- Easy Operation and Maintenance

### ABBREVIATION

Describes the acronyms used in this manual.

## Conventions

The following types of paragraphs contain special information that must be carefully read and thoroughly understood. Such information may or may not be enclosed in a rectangular box, separating it from the main text, but is always preceded by an icon and/or a bold title.


**NOTE**

Indicates additional information as a reference.

## WEEE Symbol Information

This marking on the product, accessories or literature indicates that the product and its electronic accessories (e.g. charger, headset, USB cable) should not be disposed of with other household waste at the end of their working life. To prevent possible harm to the environment or human health from uncontrolled waste disposal, please separate these items from other types of waste and recycle them responsibly to promote the sustainable reuse of material resources.

Household users should contact either the retailer where they purchased this product, or their local government office, for details of where and how they can take these items for environmentally safe recycling.

Business users should contact their supplier and check the terms and conditions of the purchase contract. This product and its electronic accessories should not be mixed with other commercial wastes for disposal.

## BATTERY Symbol Information

***Correct disposal of batteries in this product***

***(Applicable in countries with separate collection systems.)***

The marking on the battery, manual or packaging indicates that the battery in this product should not be disposed of with other household waste. Where marked, the chemical symbols Hg, Cd or Pb indicate that the battery contains mercury, cadmium or lead above the reference levels in EC Directive 2006/66.

The battery incorporated in this product is not user replaceable. For information on its replacement, please contact your service provider. Do not attempt to remove the battery or dispose it in a fire. Do not disassemble, crush, or puncture the battery. If you intend to discard the product, the waste collection site will take the appropriate measures for the recycling and treatment of the product, including the battery.

## Revision History

| VERSION | DATE OF ISSUE | REMARKS |
|---|---|---|
| 1.0 | 09. 2013. | First Version |

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# CHAPTER 1. Network Architecture

## 1.1 eSmallCell Network Configuration

A network which LTE eSmallCell belongs to consists of the eSmallCell, Small Cell Element Management System (EMS), Small Cell Gateway, Small Cell GW EMS, Evolved Packet Core (EPC), etc. A Subnet of the Packet Data Network (PDN), which allows the User Equipment (UE) to access external networks, comprises multiple eSmallCells and Small Cell Gateway/EPC (MME and S-GW/P-GW).
The network configuration of the eSmallCell is as follows:

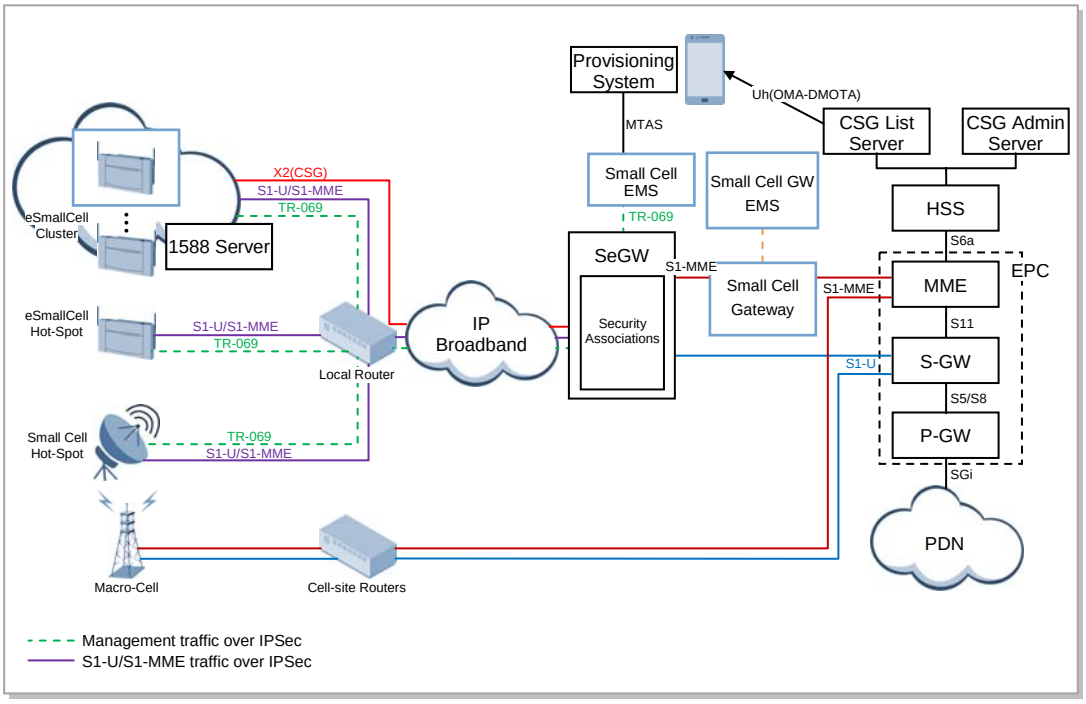



**Figure 1. LTE eSmallCell Network Architecture**

### eSmallCell

The eSmallCell is located between the UE and Small Cell Gateway/EPC. It processes packet calls by connecting to the UE wirelessly according to the LTE air standard.
The eSmallCell is responsible for transmission and receipt of wireless signals, modulation and demodulation of packet traffic signals, packet scheduling for efficient utilization of wireless resources, Hybrid Automatic Repeat request (HARQ)/ARQ processing, Packet Data Convergence Protocol (PDCP) for packet header compression, and wireless resources control.
In addition, the eSmallCell performs handover by interworking with the Small Cell Gateway/EPC.

### EPC

The EPC is a system located between the eSmallCell/Small Cell Gateway and PDN.
The subcomponents of the EPC are the Mobility Management Entity (MME), Serving GW (S-GW) and PDN GW (P-GW).

- MME: Processes control messages using the NAS signaling protocol with the eSmallCell and performs control plane functions such as UE mobility management, Tracking Area (TA) list management, and bearer and session management.
- S-GW: Acts as the anchor for the user plane between the 2G/3G access system and the LTE system, and manages and changes the packet transmission layer for downlink/ uplink data.
- P-GW: Allocates an IP address to the UE, acts as the anchor for mobility between the LTE and non-3GPP access systems, and manages/changes charging and the transmission rate according to the service level.

### Small Cell Gateway

Small Cell Gateway manages the eSmallCell and interworks with the EPC network by the eSmallCell aggregation. From the view of EPC, Small Cell Gateway acts as an eNB; from the view of eNB, it acts as an EPC, i.e. the representative eNB for the EPC.

### Small Cell EMS

The Small Cell EMS provides the user interface for the operator to operate and maintain the eSmallCell. The Small Cell EMS is responsible for software management, configuration management, performance management and fault management.
Also, the EMS interworks with service provider’s Network Management System (NMS) and carries out the Plug and Play (PnP) and SON related functions.

### Home Subscriber Server (HSS)

The HSS is a database management system that stores and manages the parameters and location information for all registered mobile subscribers. The HSS manages key data such as the mobile subscriber’s access capability, basic services and supplementary services, and provides a routing function to the subscribed receivers.

### Security Gateway (SeGW)

SeGW provides the security tunneling to the eSmallCell connected through the public IP network. To configure the tunnel, SeGW performs the authentication of the eSmallCell by interworking with the AAA server and sets the IPSec security tunneling to the authenticated eSmallCell only.
SeGW also provides the network protection through firewall and anti-attack features.

### Small Cell GW EMS

Small Cell GW EMS is the system to manage Small Cell Gateway. It manages the configuration, error, status, performance, statistics providing a Graphic User Interface (GUI) for the convenience of the user. Also, the EMS interworks with service provider's NMS.


NOTE

**CSG Server**

Refer to the '4.4 CSG function'.

# 1.2 Interface Specifications

eSmallCell supports the following interfaces for interworking with NEs:

| Target System | Interface Name | Physical Interface |
|---|---|---|
| Small Cell Gateway | S1-MME | GE/FE |
| | S1-U | GE/FE |
| MME | S1-MME | GE/FE |
| S-GW | S1-U | GE/FE |
| eSmallCell | X2-C/X2-U | GE/FE |
| Small Cell EMS | TR-069/FTP | GE/FE |
| UE | Uu | Air |

### S1 Interface Protocol Stack

The following diagram shows the protocol stack for the S1 interface control plane.

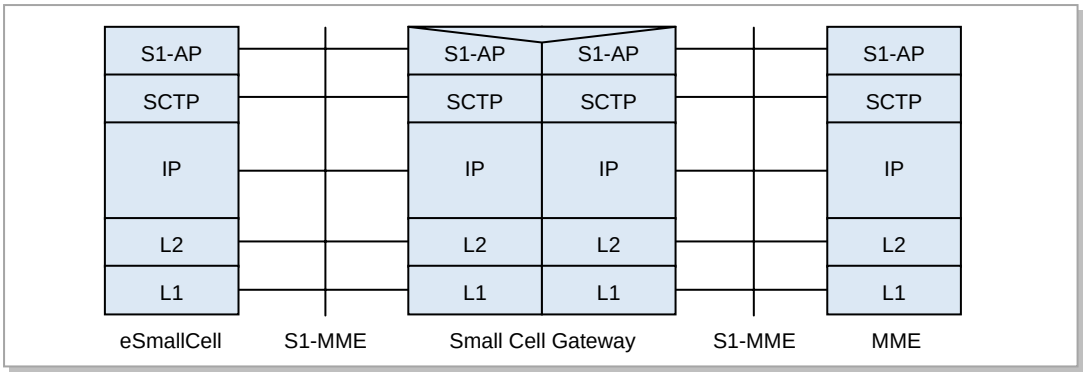



**Figure 2. S1 Protocol Stack_Control Plane (S1-MME)**

The following diagram shows the protocol stack for the S1 interface user plane.

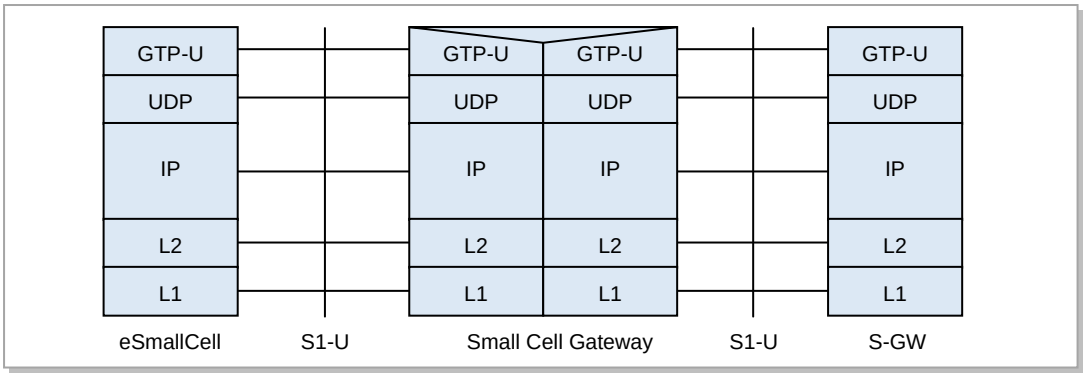



**Figure 3. S1 Protocol Stack_Control Plane (S1-MME)**

## Uu Interface Protocol Stack

The following diagram shows the protocol stack for the Uu interface.

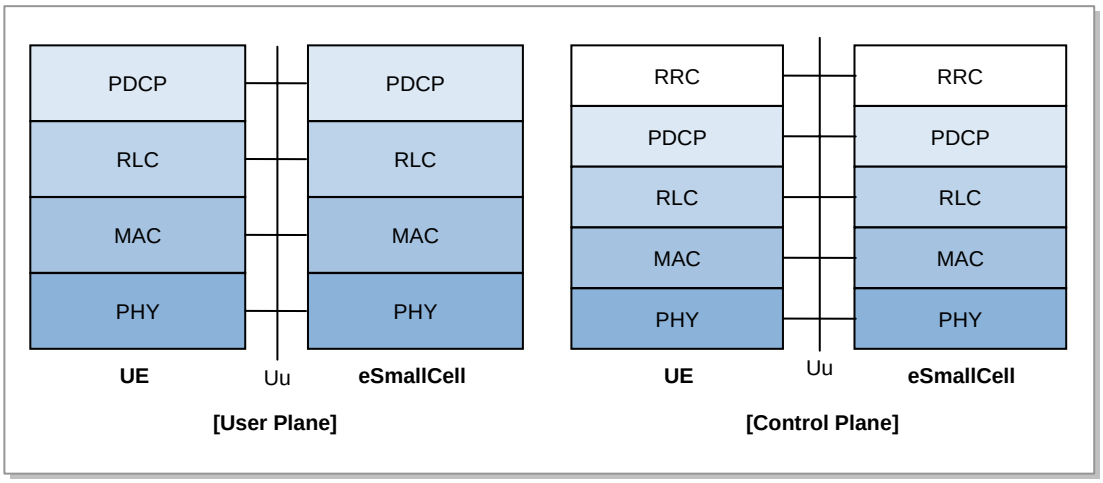



**Figure 4. Uu Protocol Stack**

## X2 Interface Protocol Stack

The following diagram shows the protocol stack for the X2 interface between eSmallCells.

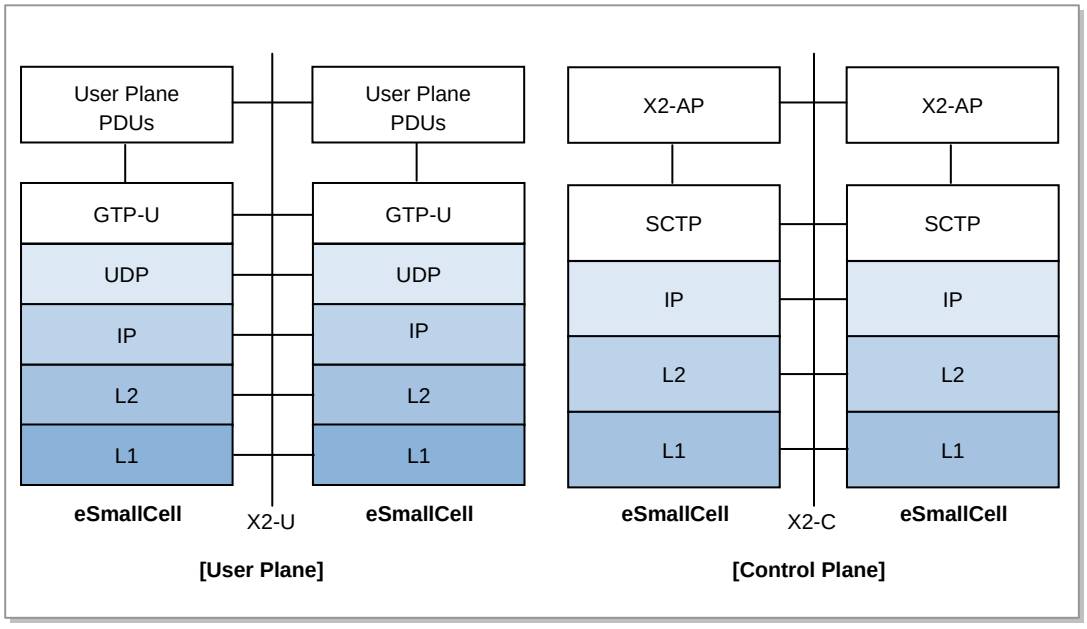



**Figure 5. X2 Protocol Stack**

## Protocol Stack for Interworking with Small Cell EMS

The following diagram shows the protocol stack for the connection between eSmallCell and Small Cell EMS.

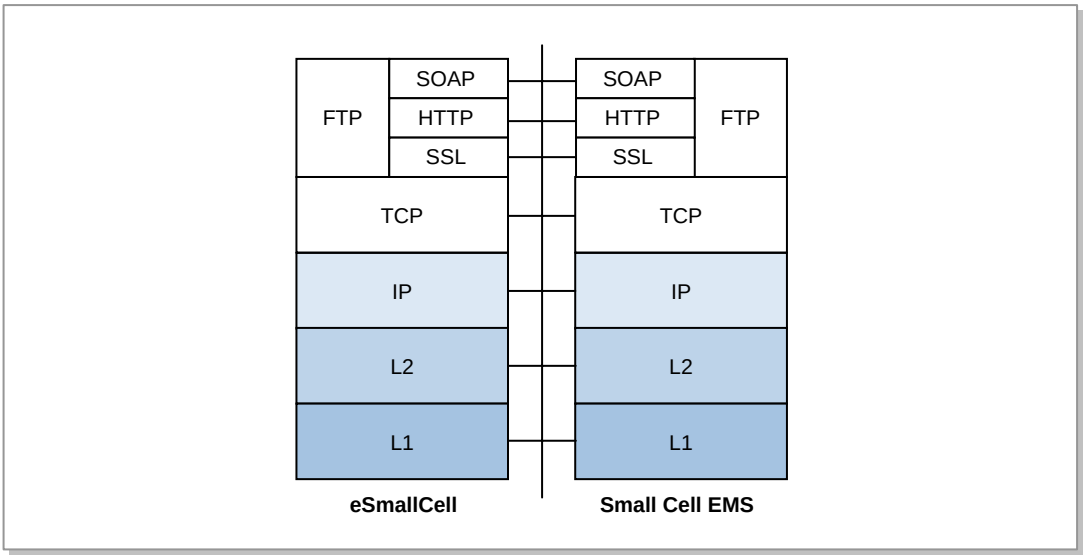



**Figure 6. Protocol Stack for Interworking with Small Cell EMS**

# CHAPTER 2. System Hardware Structure

## 2.1 Introduction to eSmallCell

eSmallCell, an LTE eNB, is located between the UE and the Small Cell Gateway/EPC. It provides mobile communications services to subscribers according to the LTE air interface standard.
The eSmallCell transmits/receives radio signals to/from the UE and processes the modulation and demodulation of packet traffic signals. The eSmallCell is also responsible for packet scheduling and radio bandwidth allocation and performs handover via interface with the Small Cell Gateway/EPC.

The eSmallCell can be installed vertically or horizontally; and it can be installed on the wall, floor or ceiling by using the mount brackets. The eSmallCell is an all-in-one unit. If a fault occurs, the unit must be replaced with new one.

The configuration of the eSmallCell is shown below:

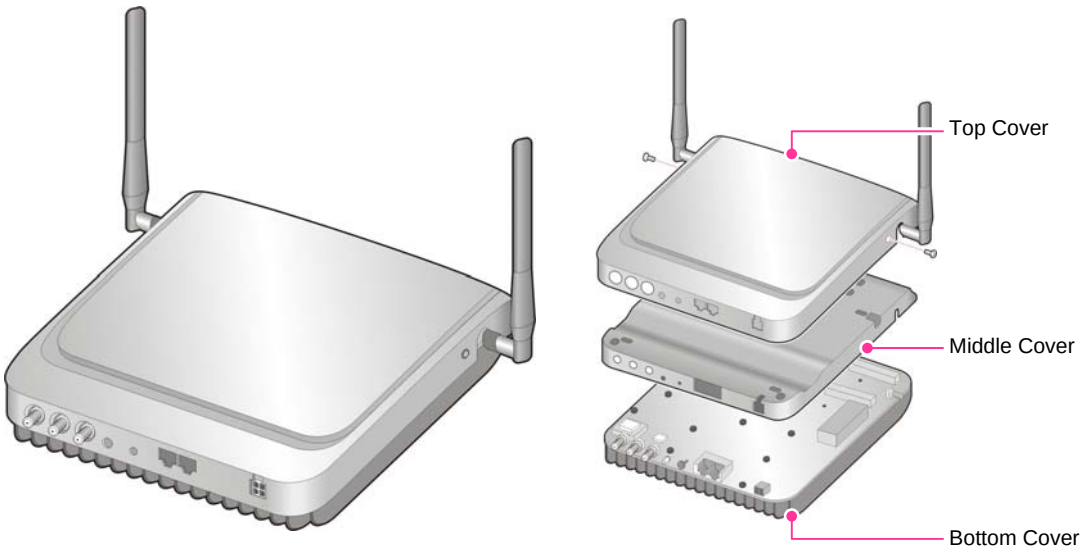



**Figure 7. eSmallCell Configuration**

# 2.2 eSmallCell (L7IA)

The eSmallCell consists of LTE 7 baseband and transceiver Integrated board Assembly (L7IA) which is the digital & RF board.

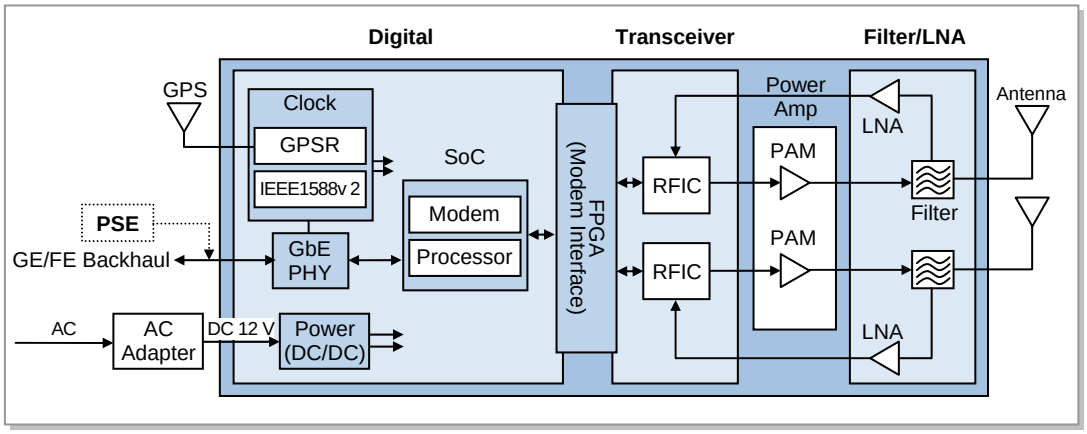



**Figure 8. Internal Configuration of eSmallCell**

The L7IA performs the functions of main controller, network interface, clock generation & distribution, modem, transceiver, and power amplifier function. The transceiver performs the Digital Up Conversion (DUC)/Digital Down Conversion (DDC), Crest Factor Reduction (CFR), linearization and Digital to Analog convert (DAC)/Analog to Digital convert (ADC) functions. Moreover, the L7IA performs the spurious wave suppression function and has the built-in Low Noise Amplifier (LNA).
The L7IA operates with 1 Carrier/Omni 2Tx/2Rx and the maximum output of the L7IA is 250 mW/path for the output port.

| Item | Description |
|---|---|
| Digital Processing Function | SoC function<br>- Performs the main processor functions of the system<br>- Performs the call processing, resource allocation, operation, and maintenance functions<br>- Processes GTP, PDCP, OAM, RRC and RRM<br>- Processes RLC and MAC/PHY<br>- Processes OFDMA/SC-FDMA channel<br>- Processes subscriber data traffic<br>- Collects alarms and reports them to Small Cell EMS<br>- Controls IEEE1588v2<br><br>Other digital processing functions<br>- Receives GPS signals and generates and supplies clocks<br>- Synchronizes using IEEE 1588v2 packet<br>- Supports backhaul (GE/FE) |
| Transceiver Function | - Supports 5/10 MHz 1 Carrier/Omni 2Tx/2Rx |

| Item | Description |
|---|---|
| | - Convert RF uplink/downlink |
| Power Amplifier Function | - Supports 5/10 MHz 1 Carrier/Omni 2Tx/2Rx<br>- Max. output 250 + 250 mW (for the external antenna port of the enclosure) |
| Filter and LNA Function | - Filters transmitted/received RF signals<br>- Performs LNA function for Rx signals |

### Main Controller Function

The main processor of the eSmallCell takes the highest role, and performs the communication path setup between UE and Small Cell Gateway/EPC, system operation and maintenance, etc.
It also manages the status for all hardware/software in the eSmallCell, allocates and manages resources, collects alarms, and reports all status information to the eSmallCell EMS.

### Clock Generation and Distribution Function

The L7IA is equipped with Beyond Enhanced GPS Engine Module (BEGEM) and IEEE1588v2 block. The BEGEM enables each block of the eSmallCell to operate under a synchronized clock system.
The BEGEM creates the PP2S (Even Clock) and digital 10 MHz using the synchronization signal received via the GPS antenna while the IEEE1588v2 block creates the 1 PPS and digital 10 MHz synchronized with the IEEE1588v2 Master and each delivers the created data to the Clock Generation & Distribution block of the L7IA.
The Clock Generation & Distribution block generates the system clock (30.72 MHz), PP2S (Even clock), 1 PPS, and System Frame Number (SFN) for synchronization using the signals received, and distributes them to the hardware blocks in the system.
The clock distributed in the system is used to keep the internal synchronization in the eSmallCell and operate the system.
The Clock Generation & Distribution block also generates the 1PPS which is the reference clock used for the measuring equipment or repeater. And, the BEGEM also transmits time information and location information through the TOD path.

### Network Interface Function

The L7IA interfaces with the Small Cell Gateway/EPC via Gigabit Ethernet or Fast Ethernet.

### Subscriber Channel Processing Function

The L7IA is equipped with the modem supporting the LTE standard physical layer to process the OFDMA/SC-FDMA channel, and the DSP processes the RLC/MAC.
The modem modulates the packet data received from upper level and transmits it to the transceiver. Reversely, the modem demodulates the packet data received from the transceiver, converts them to the format which is defined in the LTE standard physical layer specifications, and transmits them to the upper processor.

### 2Tx/2Rx MIMO Support

The RF part of the L7IA consists of transceiver and AMP, and supports the RF path of the 2Tx/2Rx. The maximum output is 250 mW/path for the external antenna port of the enclosure.

### DAC/ADC and Power Amplification

For the downlink, the baseband signals are converted to analog signals through the Digital to Analog Converter (DAC). The frequency of those analog signals is up converted through the modulator and then those signals are amplified into high-power RF signals through the power amplifier.
For the uplink, the frequency of the signals where low noise is amplified at LNA of L7IA is down converted through the demodulator. These down-converted frequency signals are converted to baseband signals through the Analog to Digital Converter (ADC).
The converted baseband signals are transmitted to the modem.

### Reset Function

The L7IA can reset the hardware remotely. The reset command is transmitted to the system's CPLD upon the Small Cell EMS's command, and the CPLD monitors it and resets the board power.

### Factory Reset Function

When the user presses the RESET button for 10 or more seconds, the system recognizes it and then becomes initialized as a factory default mode. At the time, only the value that the user can set is changed to the factory default value and the set value is maintained in the Small Cell EMS during the operation.
However, if the factory reset button is pressed before the eSmallCell is normally operated (during the booting of the initialization), it will not respond.

### Filter and LNA Function

The L7IA includes a filter and LNA, and suppresses the out-of-band spurious wave radiation. In the downlink path of the L7IA, the high-power amplified RF signal is transmitted to the antenna through the filter after satisfying the spectrum mask defined for each region. In the uplink path of the L7IA, the RF signal received via the filter is transmitted to the digital processing part of the L7IA through low-noise amplification in the LNA.

# 2.3 External Interface

The external interface of the eSmallCell is as follows:

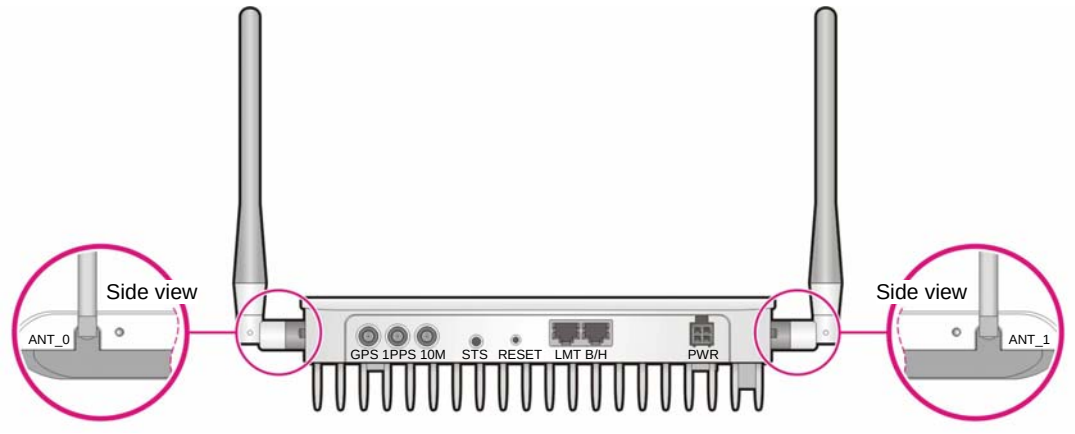



**Figure 9. External Interface of eSmallCell**

## Connector

| Port Name | Description | Port Count | Connector Type |
|---|---|---|---|
| ANT_0, ANT_1 | RF antenna interface | 2 ports | SMA female |
| GPS | GPS L1 interface | 1 port | SMA female |
| 1PPS | 1PPS clock | 1 port | SMA female |
| 10M | Digital 10 MHz clock | 1 port | SMA female |
| RESET | Factory Reset Switch | 1 port | - |
| LMT | Local management interface (100 Base-Tx/1000 Base-Tx) | 1 port | RJ-45 |
| B/H | Backhaul interface (100 Base-Tx/1000 Base-Tx) | 1 port | RJ-45 |
| PWR | Power | 1 port | Typo 4P |

## LED(STS)

| LED Status | | Description |
|---|---|---|
| ● | Red on | - Hardware reset<br>- Abnormal Power |
| ● | Orange on | - Booting completed<br>- Backhaul link is down |
| ◐ | Orange blinking | eSmallCell IP acquisition (DHCP) |
| ◐ | Green blinking | Normal operation |
| ◐ | Red blinking | GPSR Function Fail or No Current PTP Master Locking failure |
| ○ | LED off | No power supplied |

# 2.4 Cables and Antennas

### Ethernet Cable

Ethernet cables for backhaul (B/H) and PSE are connected as follows:

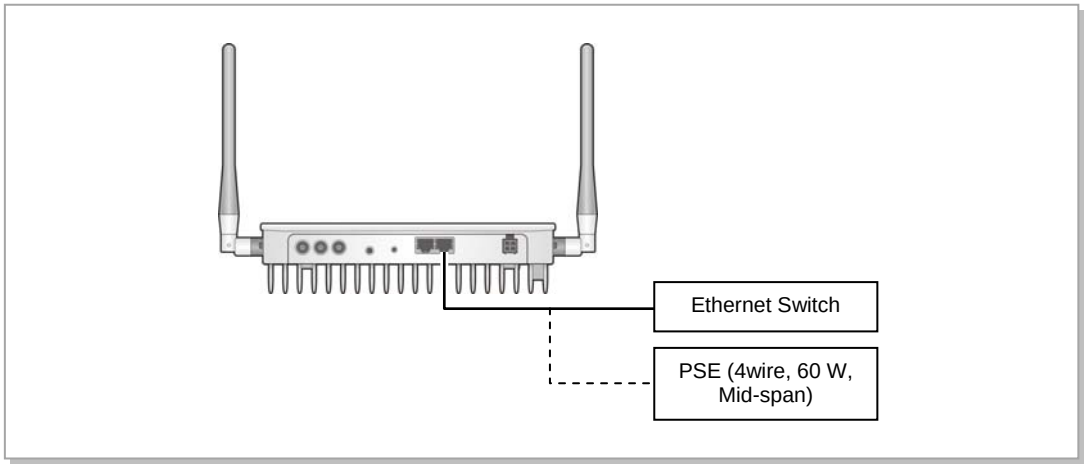



**Figure 10. eSmallCell Ethernet Cable Connection**

The specifications of the Ethernet cable are as follows:

| Item | Specification |
|---|---|
| Modular Plug | RJ-45, Miniature 8-Position Unkeyed Plug |
| Category | CAT5e |
| Pair | 4 Pair |
| Cable gauge | 24 AWG |
| Cable type | UTP |
| Cable length | 2 m |
| Cable color | gray |

## Indoor (External) GPS Antenna, GPS Extension, RF Antenna, RF Extension Cable

Indoor (external) GPS antenna, GPS extension cable, RF antenna, and RF extension cables (option) are connected as follows:

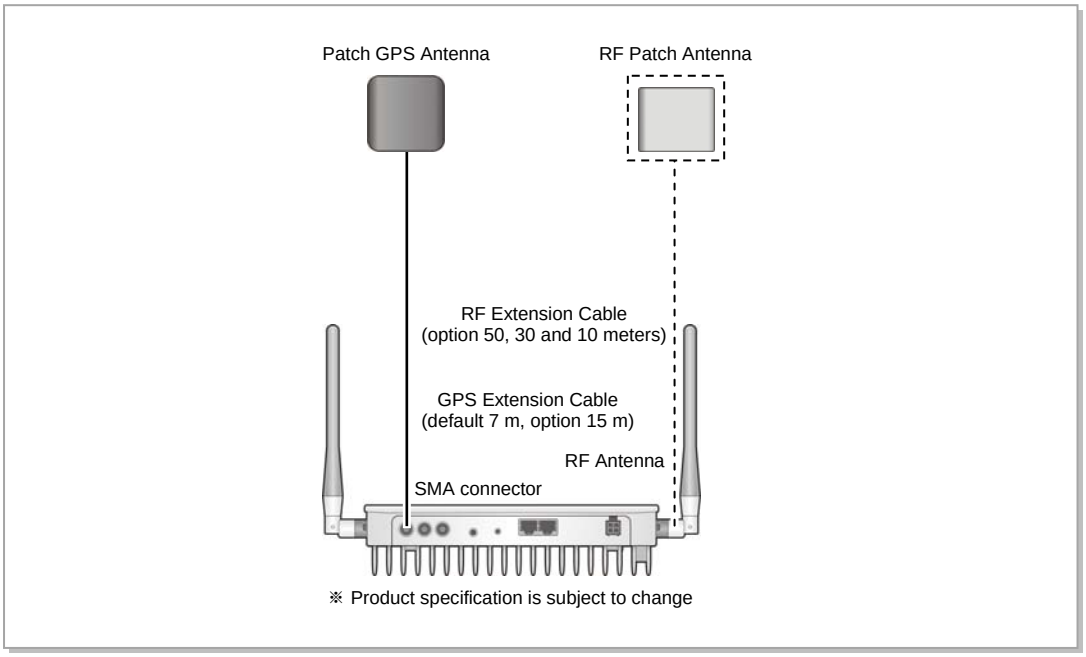



**Figure 11. GPS and RF Cable Connection**

NOTE

RF patch antenna is not provided by Samsung.

The specifications of the indoor (external) GPS antenna are as follows:

| Item | | Specification |
|---|---|---|
| Patch Antenna | Frequency Range | 1575.42 ± 1 MHz (Note1) |
| | Gain @ Zenith | +3 dBi |
| | I/O Impedance | 50 ohm |
| LNA | Gain | 35 dB min |
| | Noise Figure | 2.0 dB (Max. @ Operation temperature) |
| | Voltage | 3.0~5.5 VDC |
| | Current | 30 mA @ 3 VDC (Max) |
| | Impedance | 50 ohm |
| Cable | Type | RG-174/U |
| | Length | 7 meters |

| Item | | Specification |
|---|---|---|
| | (except connector) | |
| | Attenuation | Max. 13 dB |
| Connector | type | SMA Male (Straight) |
| Size | L × W × H | 50 × 50 × 15 mm (except for cable/connector) |
| Environment | Operating temperature | -30~80°C |
| | humidity | 5~100 % |
| Color | Antenna & Cable | Black |
| Etc. | Mount | Including Magnet on the bottom side |

The specifications of the RF antenna are as follows:

| Item | Specification |
|---|---|
| Frequency | 747MHz~787MHz<br>1,710MHz~1,755MHz<br>2,110MHz~2,155MHz |
| Gain | 2dBi |
| VSWR | < 2.0 |
| Impedance | 50ohm |
| Connector | SMA |
| Size | Φ18 x 182mm |

## Power Cord and Power Supply

Power cord and power supply are connected as follows:

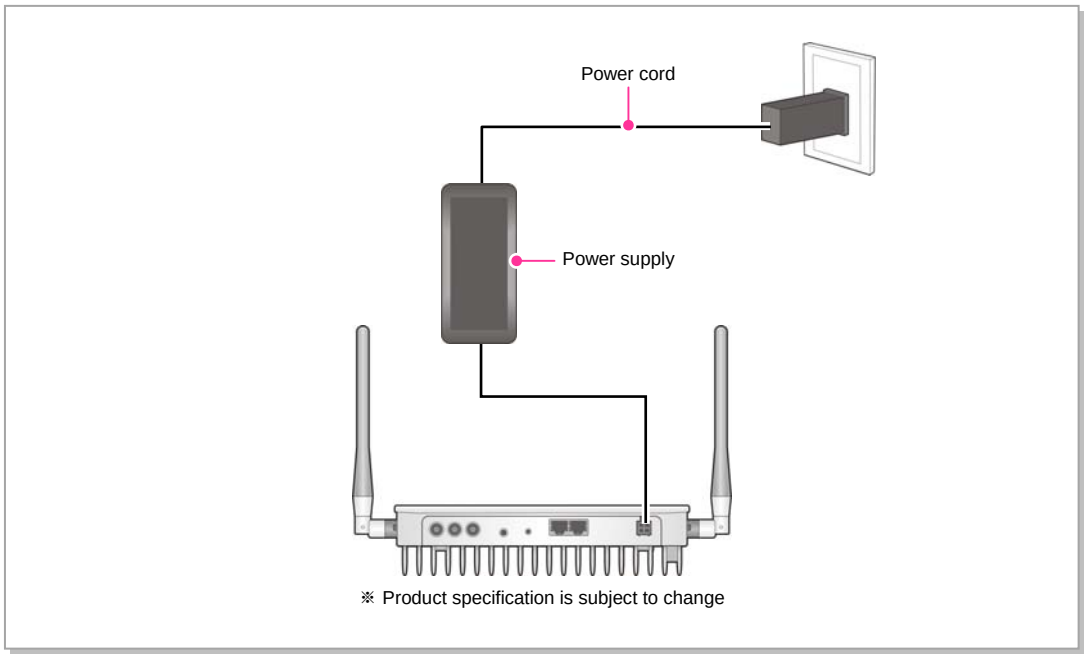


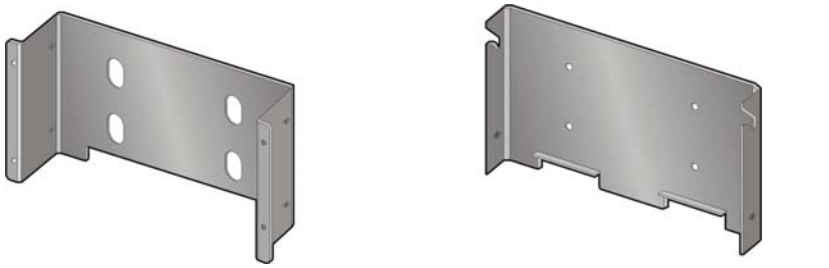

**Figure 12. Power Cord and Power Supply**

The specifications of the power cord and power supply are as follows:

| Item | | Specification |
|---|---|---|
| Power Cord | Length | 1.5 meters |
| | Color | Black |
| Power Supply | Input voltage | 105-125 VAC @ 60 Hz (± 5 % of the Input Voltage) |
| | Output voltage | 12 VDC (± 5 %) |
| | Operating temperature | -5~50°C |
| | Operating Humidity | 5~99 % |
| | Dust | GR-63-CORE 4.5 |
| | Label | Product name Manufacturer's name Model number Electrical characteristics (output voltage, amperage and polarity) eSmallCell Manufacturer's name Etc. |

# 2.5 Mount Bracket

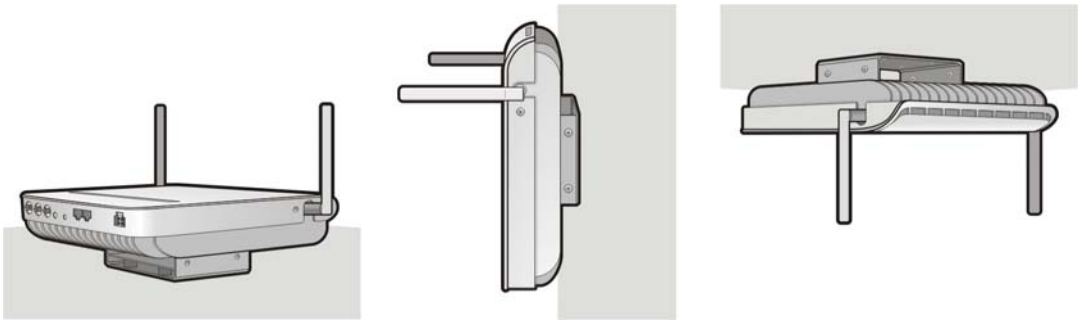
The following figure shows a bracket required when the eSmallCell is mounted on the floor, wall or ceiling.



[eSmallCell-Side Bracket] [Floor, Wall and Ceiling-Side Bracket]

**Figure 13. Mount Bracket Configuration**

The eSmallCell may be installed in the following shape by mounting the mount bracket:



[Floor] [Wall] [Ceiling]

**Figure 14. eSmallCell Installation (Example)**

# 2.6 Specifications

## Key Specifications

The key specifications of the eSmallCell are as follows:

| Item | Specifications |
|---|---|
| Operating Frequency (selective) | - Band 4 (UL: 1,710~1,755 MHz, DL: 2,110~2,155 MHz)<br>- Band 13 (UL: 777~787 MHz, DL: 746~756 MHz) |
| Channel Bandwidth | 5/10 MHz |
| Capacity | 1 Carrier/Omni |
| Antenna Configuration | 2Tx/2Rx |
| RF Output Power | 250 mW/Path (Total 500 mW) |
| Active UE | 64 Active UE (=RRC connected UE) |
| Backhaul Interface | 100 Base-TX/1000 Base-T (RJ45) |
| Synchronization (selective) | AGPS or IEEE1588v2 |
| Holdover | AGPS < 1 min, IEEE1588v2 cannot support Holdover |
| Operational temperature | 0~50°C |
| Humidity | 8~95 % (Non-condensing, not to exceed 30 $g/m^3$ absolute humidity) |
| EMC/Safety/Dust Rating | FCC Part 15/UL 60950/IP5X |
| Cooling | Convection cooling |
| O&M protocol | TR-069 |
| Security | IPSec |
| Installation | Wall, Floor and Ceiling |
| Volume/Weight | - Volume: 3.39 L = 228.2 (w) × 269.3 (h) × 55.2 (d) mm<br>- Weight: 2.4 kg |
| Power Supply (selective) | AC 105-125 VAC @ 60 Hz (± 5 % of the Input Voltage) with external adaptor or High power Power over Ethernet (PoE, 60 W) |
| Power Consumption | 45 W with AC adapter/51 W with High Power PoE |

## IEEE1588v2 Specifications

The IEEE1588v2 specifications for the eSmallCell are as follows:

| Item | Specifications |
|---|---|
| Clock Source | 1588 Grand Master |
| Accuracy/Stability | ± 0.05 ppm (frequency) |


**Synchronization Accuracy of IEEE1588v2**

IEEE1588v2 satisfies the synchronization accuracy under the conditions defined in the ITU-T G.8261 Appendix VI two-way protocol (Test Case 12-17) and G.8271.

## Ambient Conditions

This section describes the operating temperature, humidity level and other ambient conditions and related standard of the eSmallCell.

| Item | Range |
|---|---|
| Operating Temperature | 0~50°C |
| Storage Temperature | -40~70°C |
| Operating Humidity | 5~90 % (RH) |
| Storage Humidity | 5~95 % (RH) |
| Altitude | -60~1,800 m @ 50°C<br>1,800~4,000 m @ 40°C |
| Dust Rating | IEC60529, IP2X |
| Fire Test | UL2043 |


**Fire Test at Installation on Ceiling**

Because the top cover and AC/DC adaptor of the eSmallCell are made of plastic, when the eSmallCell is installed inside the ceiling, it is recommended to remove the top cover and use the PoE.

# CHAPTER 3. System Software Structure

## 3.1 Basic Software Structure

The software of the eNB is divided into three parts: Kernel Space (OS/DD), Forwarding Space (Transport: NPC/NP) and User Space (MW, IPRS, CPS, and OAM) which are described below.

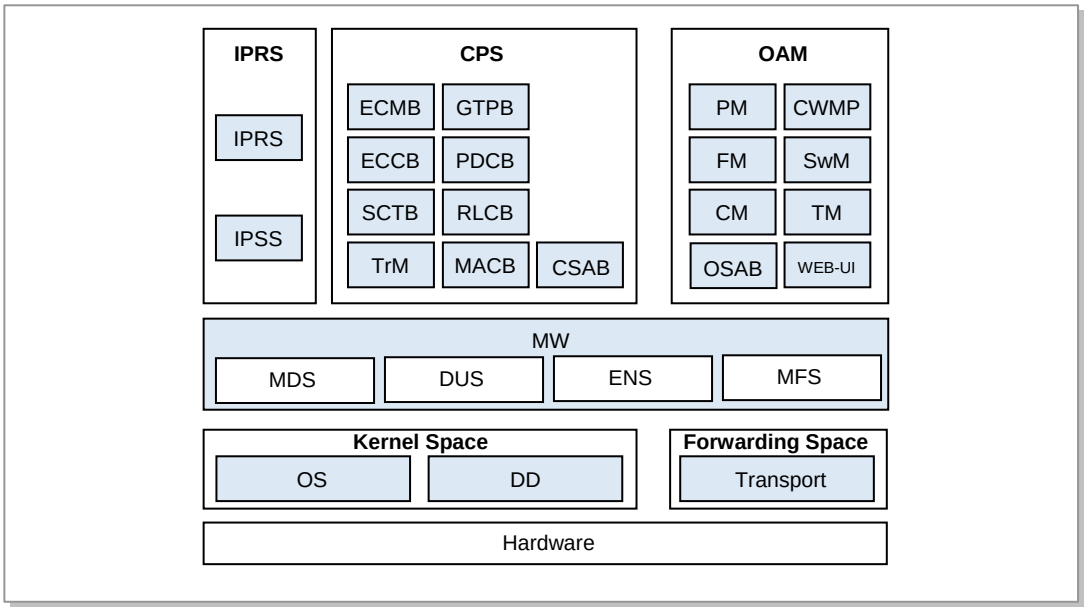



**Figure 15. eSmallCell Software Structure**

### Operating System (OS)

The OS initializes and controls the hardware devices and ensures the software is ready to run on the hardware devices. The OS consists of a booter, kernel, Root File System (RFS), and utility.

- Booter: Performs initialization on boards. It initializes the CPU, L1/L2 Cache, UART, and MAC and the devices such as CPLD and RAM within each board, and runs the u-boot.
- Kernel Manages the operation of multiple software processes and provides various primitives to optimize the use of limited resources.

- RFS: Stores and manages the binary files, libraries, and configuration files necessary for running and operating the software in accordance with the File-system Hierarchy Standard 2.2 (FHS).
- Utility: Provides the functions for managing the complex programmable logic device (CPLD), LED, watchdog, and environment and inventory information, measuring and viewing the CPU load, and storing and managing fault information when a processor goes down.

### Device Driver (DD)

The DD allows applications to operate normally on devices that are not directly controlled from the OS in the system. The DD consists of the physical DD and virtual DD.

- Physical DD: Provides the interface through which an upper application can configure, control, and monitor the external devices of the processor. (Switch device driver and Ethernet MAC driver, etc.)
- Virtual DD: For the physical network interfaces, virtual interfaces are created on the kernel so that the upper applications may control the virtual interfaces instead of controlling the physical network interfaces directly.

### Transport

The NP is the software which processes the packets required for backhaul interface.
The functions of the NP are as follows:

- Packet Rx/Tx
- MAC filtering
- IP packet forwarding
- IP fragmentation/reassembly
- VLAN termination

### Middleware (MW)

The MW ensures seamless communication between OS and applications on various hardware environments.

- Message Delivery Service (MDS): Provides all services related to message transmitting and receiving.
- Debugging Utility Service (DUS): Provides the function for transmitting debugging information and command between the applications and the operator.
- Event Notification Service (ENS): Adds and manages various events such as timers, and provides the function for transmitting an event message to the destination at the time when it is needed.
- Miscellaneous Function Service (MFS): The MFS is responsible for all hardware-dependent functions, such as accessing physical addresses of hardware devices.

#### IP Routing Software (IPRS)

The IPRS is the software that provides the IP routing and IP security function for the system backhaul. The IPRS is configured with IPRS and IP Security Software (IPSS), and each of them provide the functions as follows.

- IPRS: Collects and manages the system configuration and status information necessary for IP routing. Based on this data, the IPRS provides the function for creating routing information.
  - Managing Ethernet and VLAN-TE
  - IP addresses management
  - IP routing information management
- IPSS: Provides the QoS and security function for the IP backhaul.
  - Backhaul bandwidth restriction
  - DSCP to CoS mapping
  - IPSec
  - ACL

### 3.1.1 CPS Block

The Call Processing Software (CPS) block performs the resource management of the LTE eNB and the call processing function in the eNB defined in the 3GPP and performs the interface function with the EPC, UE, and neighbor eSmallCells. The CPS consists of the eNB Control Processing Subsystem (ECS) which is responsible for network access and call control functions, and the eNB Data processing Subsystem (EDS) which is responsible for user traffic handling.
The ECS consists of eNB Common Management Block (ECMB), eNB Call Control Block (ECCB), SCTP Block (SCTB), CPS SON Agent Block (CSAB) and Trace Management (TrM); and the EDS consists of GPRS Tunneling Protocol Block (GTPB), PDCP control Block (PDCB), Radio Link Control Block (RLCB) and Medium Access Control Block (MACB).

The major functions of the CPS blocks are as follows:

#### ECMB

- Setting/Releasing cell
- Transmitting system information
- eSmallCell overload control: controls the system overload depending on CPU load status
- Access barring control: controls the access barring parameters of SIB2
- Resource measurement control: controls the measurement of the resource status in the system, such as PRB usage and PDB
- Transmission of cell load information: provides interface for ICIC functions with transmission of the X2 load information message

### ECCB

- Radio resource management
- Idle to Active status transition
- Setting/changing/releasing bearer
- Paging Functions
- MME selection/load balancing
- Call admission control
- Security function
- Handover control
- UE measurement control
- Statistics processing

### SCTB

- S1-Cterfacing
- X2-C interfacing

### CSAB

- Collection of statistics regarding the mobility robustness optimization
- Collection of statistics regarding the RACH optimization

### TrM

- Call Trace function
- Call Summary Log (CSL) function

### GTPB

- GTP tunnel control
- GTP management
- GTP data transmission

### PDCB

- Header compression or decompression (ROHC only)
- Transmitting user data and control plane data
- PDCP sequence number maintenance
- DL/UL data forwarding at handover
- Ciphering and deciphering for user data and control data
- Control data integrity protection
- Timer-based PDCP SDU discarding

#### RLCB

- Transmission for the upper layer PDU
- ARQ function used for the AM mode data transmission
- RLC SDU concatenation, segmentation and reassembly
- Re-segmentation of RLC data PDUs
- In sequence delivery
- Duplicate detection
- RLC SDU discard
- RLC re-establishment
- Protocol error detection and recovery

#### MACB

- Mapping between the logical channel and the transport channel
- Multiplexing & de-multiplexing
- HARQ
- Transport format selection
- Priority handling between UEs
- Priority handling between logical channels of one UE

### 3.1.2 OAM Blocks

The OAM is responsible for operation and maintenance in the eSmallCell. The OAM is configured with OAM SON Agent Block (OSAB), Performance Management (PM), Fault Management (FM), Configuration Management (CM), CPE WAN Management Protocol (CWMP), Software Management (SwM), Test Management (TM), and WEB-UI.

The major functions of the OAM blocks are as follows:

#### OSAB

- System information, automatic configuration, and automatic installation
- Optimizing automatic neighbor relation

#### PM

- Collecting statistics data
- Storing statistics data
- Transmitting statistics data

### FM

- Detecting faults and reporting alarms
- Retrieving alarm
- Alarm filtering
- Setting alarm severity
- Setting alarm threshold
- Alarm correlation

### CM

Retrieval and change of configuration information

### CWMP

Processing the TR-069 message

### SwM

- Downloading and installing software and data files
- Reset of hardware unit and system
- Status monitoring of the software unit in operation
- Managing and updating the software and firmware information
- Software upgrade
- Inventory Management Functions

### TM

- Enable/disable the Orthogonal Channel Noise Simulator (OCNS)
- Setting/clearing a Model
- Ping test
- Measuring the Tx/Rx power
- Measuring the antenna Voltage Standing Wave Ratio (VSWR)

### WEB-UI

- Web Server function
- Interoperation with other OAM blocks for processing the command

# 3.2 Data Traffic Flow

## Sending Path

The user data received from the Small Cell GW/EPC passes through the network interface module and is transmitted through the Ethernet switch to the L7IA of eSmallCell.
The transmitted user data goes through baseband-level digital processing, and transmitted to the transceiver part. The transceiver up-converts the wideband baseband signal to the RF band, and the converted signal is transmitted to the antenna through the power amplifier and filter.

## Receiving Path

The RF signal received by the antenna passes through the L7IA's filter and its low noise is amplified by the LNA. This signal is converted to the data signal of baseband after the RF down-conversion in the transceiver of the L7IA. The data which passed through the SC-FDMA signaling process in the modem is converted to the Gigabit Ethernet frame and transmitted to the Small Cell GW/EPC through GE.

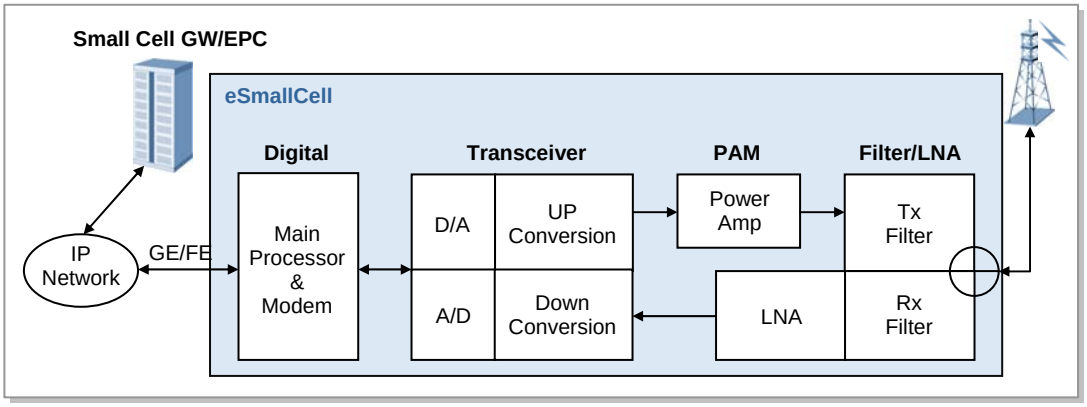



**Figure 16. Data Traffic Flow**

# 3.3 Network Sync Flow

The eSmallCell supports the GPS and IEEE1588v2 synchronization method selectively.
In case of the GPS synchronization, the GPS receiver (BEGEM) receives the synchronization signal from the GPS and creates clocks. The clocks are distributed by the clock generation & distribution part.
In case of the IEEE1588v2 packet synchronization, the IEEE1588v2 packet is received from an external IEEE 1588v2 server for the synchronization.

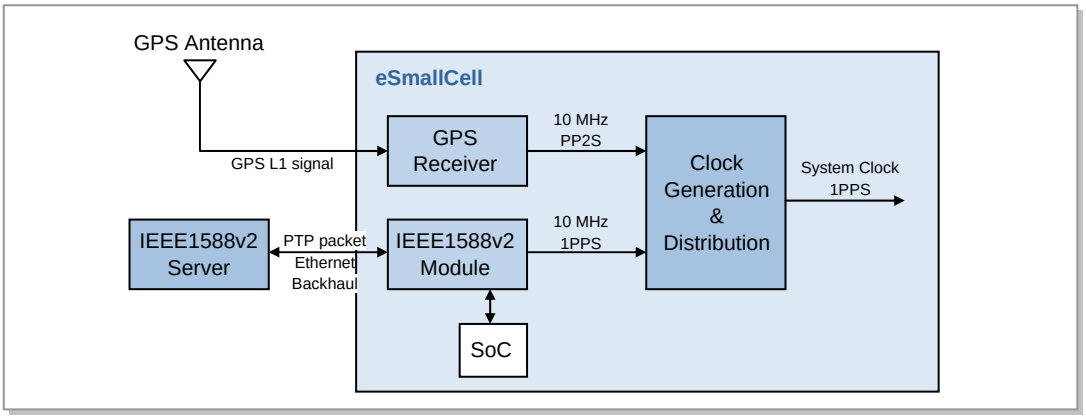



**Figure 17. Network Synchronization Flow**

# 3.4 Alarm Signal Flow

An alarm is reported as an alarm signal when a fault occurs. The L7IA collects all the alarms and report them to the LSM which is the management system.

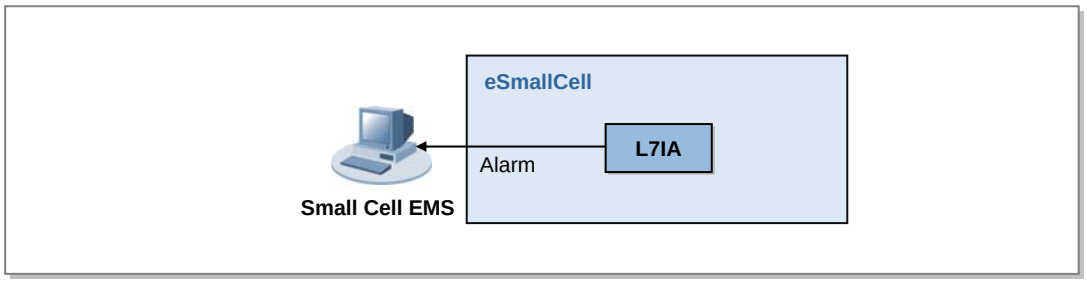



**Figure 18. Alarm flow**

# 3.5 Loading Flow

Loading is the procedure through which the processors and devices of the system can download from the Small Cell EMS the software executables, data, and other elements required to perform their functions.
At the first system initialization, the loading information is stored in the internal storage so that no unnecessary loading is carried out. When it is indicated to change software from the Small Cell EMS, a new file is downloaded from the Small Cell EMS.

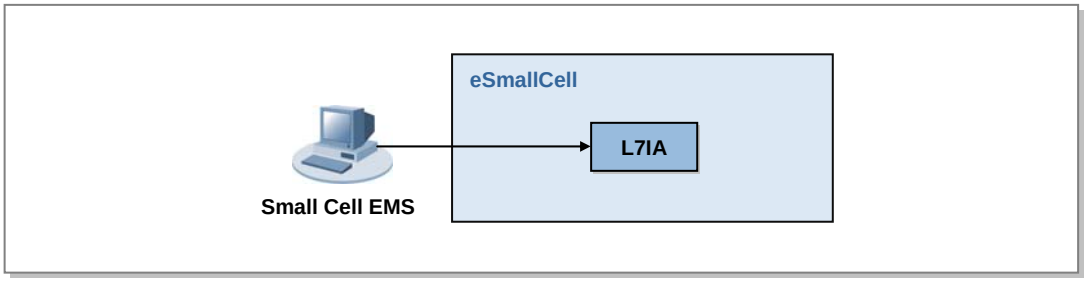



**Figure 19. Loading Signal Flow**

# 3.6 Operation and Maintenance Message Flow

The operator can check and change the status of the eSmallCell through the management system. To accomplish this, the eSmallCell provides the TR-069 protocol interworking function, and the Small Cell EMS operator can carry out the operation and maintenance functions of the eSmallCell remotely. Moreover, the operator can carry out the maintenance function using the web browser.
The statistical information provided by the eSmallCell is given to the operator in accordance with the collection interval.

The operation and maintenance in the eSmallCell is performed using the TR-069 protocol message with the Small Cell EMS. The Web UI is a type of GUI-based console terminal which directly accesses the eSmallCell to monitor the status of, operate and maintain the equipment.

The figure below shows the operation and maintenance signal flow.

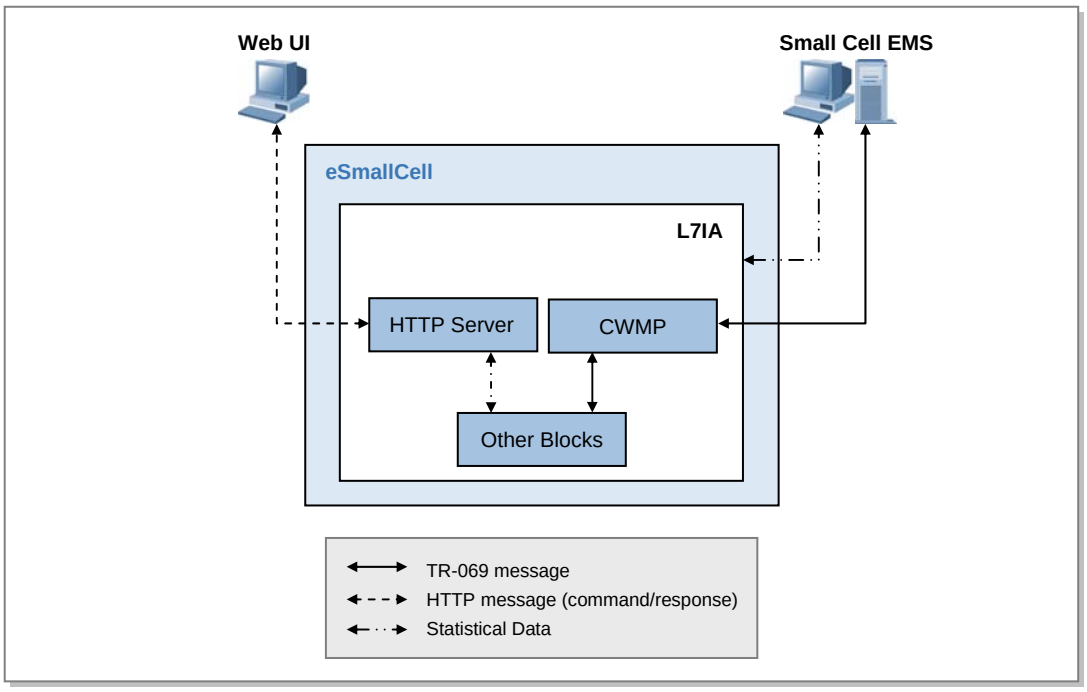



**Figure 20. Operation and Maintenance Signal Flow**

### Web UI

Web UI is a kind of GUI-based console terminal. It is a tool for viewing the status of devices by directly accessing the eSmallCell and performing a function of setting some information such as network configuration. The operator can perform Web UI only with Internet Explorer without installing separate software.

# CHAPTER 4. System Functions

The main functions of the eSmallCell are as follows:

- Physical Layer Processing
- Interference Mitigation Function
- Call Processing Function
- CSG Function
- IP Processing
- OTAR based GSP locking assistance Function
- Plug-n-Play Function
- SON Function
- Security
- Easy Operation and Maintenance


**Availability of System Features and Functions**

For availability and provision schedule of the features and functions described in the system manual, please refer to separate documentations.

## 4.1 Physical Layer Processing

The eSmallCell transmits/receives data through the radio channel between the Small Cell Gateway/EPC and UE. To do so, the eSmallCell provides the following functions.

- Downlink Reference Signal Creation and Transmission
- Downlink Synchronization Signal Creation and Transmission
- Channel Encoding/Decoding
- Modulation/Demodulation
- Resource Allocation and Scheduling
- Link Adaptation
- HARQ
- MIMO

### Downlink Reference Signal Creation and Transmission

The UE must estimate the downlink channel to perform the coherent demodulation on the physical channel in the LTE system. The LTE uses the OFDM/OFDMA-based methods for transmitting and therefore the channel can be estimated by inserting the reference symbols from the receiving terminal to the grid of each time and frequency. These reference symbols are called downlink reference signals, and there are 2 types of reference signal defined in the LTE downlink.

- Cell-specific reference signal: The cell specific reference signal is transmitted to every subframe across the entire bandwidth of the downlink cell. It is mainly used for channel estimation, MIMO rank calculation, MIMO precoding matrix selection and signal strength measurement for handover.
- UE-specific reference signal: The UE-specific reference signal is used for estimating channel for coherent demodulation of DL-SCH transmission where the beamforming method is used. ‘UE-specific’ means that the reference signal is generally used for channel estimation of a specified UE only. Therefore, the UE-specific reference signal is used in the resource block allocated for DL-SCH only, which is transmitted to the specified UE.

### Downlink Synchronization Signal Creation and Transmission

The synchronization signal is used for the initial synchronization when the UE starts to communicate with the eSmallCell. There are two types of synchronization signals: Primary Synchronization Signal (PSS) and Secondary Synchronization Signal (SSS).
The UE can obtain the cell identity through the synchronization signal. It can obtain other information about the cell through the broadcast channel. Since synchronization signals and broadcast channels are transmitted in the 1.08 MHz range, which is right in the middle of the cell’s channel bandwidth, the UE can obtain the basic cell information such as cell ID regardless of the transmission bandwidth of the eSmallCell.

### Channel Encoding/Decoding

The eSmallCell is responsible for channel encoding/decoding to correct the channel errors that occurred on a wireless channel. In LTE, the turbo coding and the 1/3 tail-biting convolutional coding are used. Turbo coding is mainly used for transmission of large data packets on downlink and uplink, while convolutional coding is used for control information transmission and broadcast channel for downlink and uplink.

### Modulation/Demodulation

For the data received over the downlink from the upper layer, the eSmallCell processes it through the baseband of the physical layer and then transmits it via a wireless channel.
At this time, to transmit a baseband signal as far as it can go via the wireless channel, the system modulates and transmits it on a specific high frequency bandwidth.
For the data received over the uplink from the UE through a wireless channel, the eSmallCell demodulates and changes it to the baseband signal to perform decoding.

### Resource Allocation and Scheduling

To support multiple accesses, the eSmallCell uses OFDMA for downlink and SC-FDMA for uplink. By allocating the 2-dimensional resources of time and frequency to multiple UEs without overlay, both methods enable the eSmallCell to communicate with multiple UEs simultaneously.
When the eSmallCell operates in the MU-MIMO mode, multiple UEs may use the same resource at the same time exceptionally. Such allocation of cell resources to multiple UEs is called scheduling and each cell has its own scheduler for this function.
The LTE scheduler of the eSmallCell allocates resources to maximize the overall throughput of the cell by considering the channel environment of each UE, the data transmission volume required, and other QoS elements. In addition, to reduce interferences with other cells, the eSmallCell can share information with the schedulers of other cells over the X2 interface.

### Link Adaptation

The wireless channel environment can become faster or slower, better or worse depending on various factors. The system is capable of increasing the transmission rate or maximizing the total cell throughput in response to the changes in the channel environment, and this is called link adaptation.
In particular, the Modulation and Coding Scheme (MCS) is used for changing the modulation method and channel coding rate according to the channel status. If the channel environment is good, the MCS increases the number of transmission bits per symbol using a high-order modulation. If the channel environment is bad, it uses a low-order modulation and a low coding rate to minimize channel errors.
In addition, in the environment where MIMO mode can be used, the eSmallCell operates in MIMO mode to increase the peak data rate of subscribers and can greatly increase the cell throughput.
If the channel information obtained is incorrect or modulation method of higher order or higher coding rate than the given channel environment is used, errors may occur.
In such cases, the errors can be corrected by the HARQ function.

### H-ARQ

The H-ARQ is a retransmission method in the physical layer, which uses the stop-and-wait protocol. The eSmallCell provides the HARQ function to retransmit or combine frames in the physical layer so that the effects of wireless channel environment changes or interference signal level changes can be minimized, which results in throughput improvement.
The LTE uses the Incremental Redundancy (IR)-based HARQ method and regards the Chase Combining (CC) method as a special case of the IR method.
The eSmallCell uses the asynchronous method for downlink and the synchronous method for uplink.

### MIMO

The eSmallCell can support the MIMO by using multiple antennas. For this purpose, the channel card of the eSmallCell has the baseband part to process the MIMO, and individual RF paths can be processed separately. The eSmallCell supports various types of the MIMO to provide the high-performance data service.

# 4.2 Interference Mitigation

## Downlink ICIC

DL ICIC is a function of allocating resources and changing power depending on the status of the channel of the UE. The ICIC function allows high power to be allocated to the UE on the edge and low power to be allocated to the UE on the center and may reduce interference between the UEs.
The operation of the Downlink ICIC is as follows:

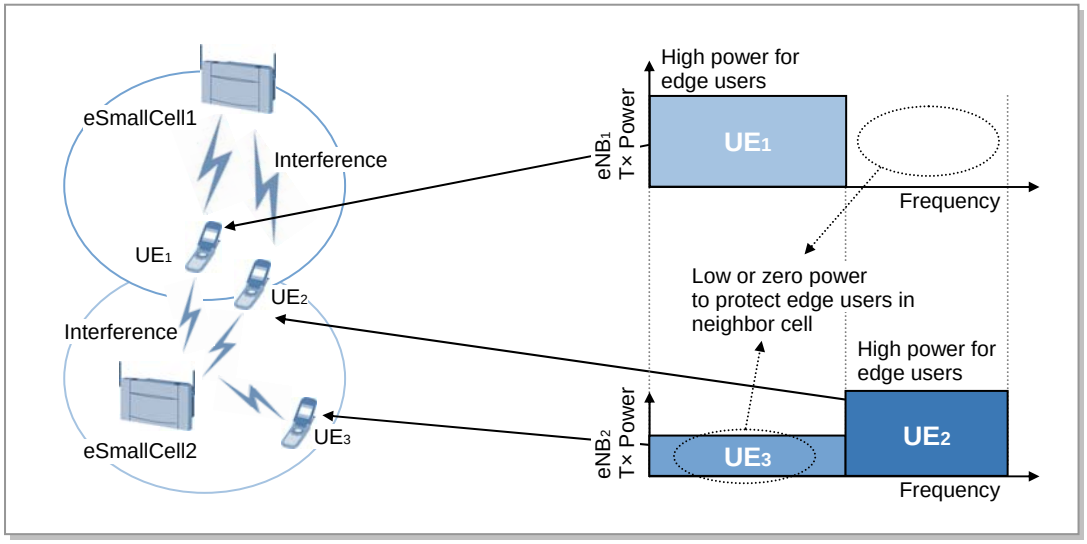



**Figure 21. Downlink ICIC Operation**

- Step 1: Channel condition
  - UE's channel condition is estimated using the CQI Feedback from UE.
  - Average CQI Threshold is considered as a criteria to qualify as a cell edge or cell center condition
- Step 2: Power control mechanism
  - If UE is estimated to be in cell center condition, UE specific DL power related parameter Pa is lowered, which results in power reduction of data subcarriers for that UE and further decreases interference to neighboring cells.
  - If UE is estimated to be in cell edge condition, Pa is increased and hence data subcarriers power is increased in order to maintain edge UE's quality.

## PUCCH Moving to Center

The eSmallCell support PUCCH Regions in the center of the carrier for Public Safety Band Uplink Interference Mitigation in Band Class 13.

## Frequency Selective Scheduling

The eSmallCell support frequency selective scheduling(Requirement is based on UE selected sub-band CQI reporting)

# 4.3 Call Processing Function

### Cell Information Transmission

In a serving cell, the eSmallCell periodically transmits a Master Information Block (MIB) and System Information Blocks (SIBs), which are system information, to allow the UE that receives them to perform proper call processing.

### Call Control and Air Resource Assignment

The eSmallCell allows the UE to be connected to or disconnected from the network. When the UE is connected to or released from the network, the eSmallCell transmits and receives the signaling messages required for call processing to and from the UE via the Uu interface, and to and from the Small Cell Gateway/EPC via the S1 interface.
When the UE connects to the network, the eSmallCell performs call control and resource allocation required for service. When the UE is disconnected from the network, the eSmallCell collects and releases the allocated resources.

### Handover

The eSmallCell supports intra-frequency or inter-frequency handover between intra-eSmallCell cells, X2 handover between eSmallCells, and S1 handover between eSmallCells. It also processes signaling and bearer for handover. At intra-eSmallCell handover, handover-related messages are transmitted via internal eSmallCell interfaces; at X2 handover, via the X2 interface; at S1 handover, via the S1 interface.
To minimize user traffic loss during X2 and S1 handovers, the eSmallCell performs the data forwarding function. The source eSmallCell provides two forwarding methods to the target eSmallCell: direct forwarding via the X2 interface and indirect forwarding via the S1 interface.
The eSmallCell allows the UE to receive traffic without loss through the data forwarding method at handover.

### Admission Control (AC)

The eSmallCell provides capacity-based admission control and QoS-based admission control for a bearer setup request from the Small Cell Gateway/EPC so that the system is not overloaded.

- Capacity-based admission control
  There is a threshold for the maximum number of connected UEs (new calls/handover calls) and a threshold for the maximum number of connected bearers that can be allowed in the eSmallCell. Call admission is determined depending on whether the connected UEs and bearers exceed the thresholds.
- QoS-based admission control
  The eSmallCell determines whether to admit a call depending on the estimated PRB usage of the newly requested bearer, the PRB usage status of the bearers in service, and the maximum acceptance limit of the PRB (per bearer type, QCI, and UL/DL).

### RLC ARQ

The eSmallCell performs the ARQ function for the RLC Acknowledged Mode (AM) only. When receiving and transmitting packet data, the RLC transmits the SDU by dividing it into units of RLC PDU at the transmitting side and the packet is retransmitted (forwarded) according to the ARQ feedback information received from the receiving side for increased reliability of the data communication.

### QoS Support

The eSmallCell receives the QoS Class Identifier (QCI) in which the QoS characteristics of the bearer are defined and the GBR, the MBR, and the Aggregated Maximum Bit Rate (UE-AMBR) from the Small Cell Gateway/EPC. It provides the QoS for the wireless section between the UE and the eSmallCell and the backhaul section between the eSmallCell and the Small Cell Gateway/S-GW.
Via the air interface, it performs retransmission to satisfy the rate control according to the GBR/MBR/UE-AMBR values, priority of bearer defined in the QCI, and scheduling considering packet delay budget, and the Packet Loss Error Rate (PLER).
Via the backhaul interface, it performs QCI-based packet classification, QCI to DSCP mapping, and marking for the QoS. It provides queuing depending on mapping results, and each queue transmits packets to the EPC according to a strict priority, etc.
In the Small Cell EMS, in addition to the QCI predefined in the specifications, operator-specific QCI and QCI-to-DSCP mapping can be set.

# 4.4 CSG Function

## Overview of CSG Function

Depending on the 3GPP standards, the access methods of the eSmallCell include closed access, open access, and hybrid access modes and the feature by each mode is as follows:

| Type | Release | Description | Example |
|---|---|---|---|
| Open | Release 8 | Grant access and offer all services to all users | Public Library, airport |
| Closed | Release 8 | - Grant access and offer all services to CSG members only.<br>- Only Emergency calls allowed for non-members | Security and backhaul use conscious organization. |
| Hybrid | Release 9 | Grant access to all users, but provide better service to CSG members | Students and Faculty on a university campus get better service than general public |

The eSmallCell describes CSG Indication and CSG Identity in the cell access information of SIB 1 to broadcast its access mode to a subscriber who intends to access. The information of SIB 1that broadcasts CSG type and CSG ID is as follows:

| Type | SIB 1 CSG contents |
|---|---|
| Open | CSG Indicator = FALSE<br>CSG ID is empty |
| Closed | CSG Indicator = TRUE<br>CSG ID = List of max. of 256 27 bit CSG IDs |
| Hybrid | CSG Indicator = FALSE<br>CSG ID = List of max. of 256 27 bit CSG IDs |

### CSG Membership Management & Access Control

The CSG list is the list of CSG IDs which each subscriber can access and the subscriber stores the CSG list as the information on the subscription of the eSmallCell. The CSG list is classified into the allowed CSG list and the operator CSG list, and the combination of the two lists is called as CSG-white list.

- Allowed CSG list: Stored in the USIM of the UE and can be modified by the operator and the subscriber.
- Operator CSG list: Possible to be modified only by the operator and be read-only by the subscriber.

The allowed CSG list that the subscriber stores must be the same as that operated in HSS and MME of the core network. The allowed CSG list must have the latest data in the core network all the time and if the allowed CSG lists between the subscriber and the core network are not matched, the data of the subscriber must be changed. If the access of the subscriber to the eSmallCell fails to be authorized, the CSG administrate server delivers the reason to the HSS/MME and reports it to the subscriber through the RRC message. At the time, the subscriber deletes the CSG ID of the current cell in the allowed CSG list that s/he stores. Through such procedures, the allowed CSG list operated by the core network is matched with that retained by the subscriber.

When the UE accesses the CSG cell, the CSG access control checks whether the UE can access the CGS cell by making the MME checking whether the CSG subscription information of the UE is matched with the CSG ID of the serving cell (member or non-member eSmallCell). If the UE is impossible to access, the access request will be rejected. Regardless of CSG subscription, the emergency call is allowed to access all the time.

In case of the hybrid cell, for the CSG subscription information, whether the UE is a member of the hybrid cell same as the CSG access control is checked. The membership information may be used for admission control and the hybrid cell may be provided as the dedicated service for the member. Contrary to the CSG access control, the hybrid cell does not reject even the access request for a non-member.

# 4.5 IP Processing

### IP QoS

The eSmallCell can provide the backhaul QoS when communicating with the EPC by supporting the Differentiated Services (DiffServ).
The eSmallCell supports 8 class DiffServ and mapping between the services classes of the user traffic received from the MS and DiffServ classes. In addition, the eSmallCell supports mapping between the Differentiated Services Code Points (DSCP) and the 802.3 Ethernet MAC service classes.

### IP Routing

Since the eSmallCell provides multiple Ethernet interfaces, it stores in the routing table the information on which Ethernet interface the IP packets will be routed to. The routing table of the eSmallCell is configured by the operator. The method for configuring the routing table is similar to the standard router configuration method.
The eSmallCell supports static routing settings, but does not support dynamic routing protocols such as Open Shortest Path First (OSPF) or Border Gateway Protocol (BGP).

### Ethernet/VLAN Interface

The eSmallCell provides Ethernet interfaces and supports the static link grouping, Virtual Local Area Network (VLAN), and Ethernet CoS functions that comply with IEEE 802.3ad for Ethernet interfaces. The MAC bridge function defined in IEEE 802.1D is not supported.
The eSmallCell allows multiple VLAN IDs to be set for an Ethernet interface.
To support Ethernet CoS, it maps the DSCP value of the IP header to the CoS value of the Ethernet header for Tx packets.

# 4.6 OTAR based GPS Locking Assistance Function

The eSmallCell supports the AGPS (Assisted GPS) operation as a supporting function to reduce the GPS locking time. The AGPS is a function of receiving the information on the satellites around the earth in advance and use the information at the GPS locking to reduce the locking time.

If the location of the eSmallCell is not defined, the AGPS function assumes that it is located on the center of the area and performs the GPS locking operation. At the time, if the location of the eSmallCell is defined to be around the current eSmallCell, it would reduce the time for the AGPS operation. Therefore, the eSmallCell supports a function of setting the approximate location information through the OTAR.

OTAR based GPS locking assistance is a function of making an initial Small Cell EMS deliver the approximate location information to the eSmallCell through the ECGI/TA to location information that has been retained if the eSmallCell scans the information on the ECGI/TA (E-UTRAN Cell Global Identifier/Tracking Area) of the neighbor macro cell to the initial Small Cell EMS through the OTAR operation. By using the delivered location information, the eSmallCell operates the AGPS operation.

# 4.7 Plug and Play Function

The Plug and Play function is a function of automatically conducting the system 'power on' to 'in-service' by automatically configuring the network parameters to minimize the items the operator sets manually at the installation place when the system is installed. The detailed functions are as follows:

- A function of automatically obtaining the eSmallCell IP address (DHCP)
  Through the connection with the DHCP server, receives outer IP address, Netmask, Gateway IP, DNS server IP, etc. to be used by the eSmallCell.
- A function of automatically obtaining the IP targeted to be connected (DNS query)
  - The eSmallCell obtains the IP address of Initial SeGW, Initial Small Cell EMS, AGPS server, etc. through the DNS query. FQDNs (Full Qualified Domain Names) to obtain the IP address is pre-stored in the eSmallCell.
  - The eSmallCell obtains the serving SeGW address through the DNS query and the serving SeGW FQDN is obtained from the Initial Small Cell EMS.
- AGPS/OTAR function to assist GPS locking
- IPSec function to protect the backhaul connection: The eSmallCell supports the IPSec function to protect the backhaul connection and uses the following configuration: IKEv2, ESP, Tunnel mode, 1 IPSec tunnel, Encryption: AES, Integrity Protection: HMAC-SHA1-96
- Automatic OAM connection
- Software and Configuration data loading
- Automatic S1/X2 setup
  - When the S1 is automatically set up, it supports the connection with two small cell gateways, and operates as primary/secondary.
  - When the connection to the primary small cell gateway is successful, use the primary small cell gateway and the S1 connection. When the connection to the primary small cell gateway fails, attempt at the secondary small cell gateway and the S1 connection.
- Self-Test function

# 4.8 SON Function

The SON function supports the self-configuration, self-establishment and self-optimization function.

### Self-Configuration

Self-configuration enable automatic setup of radio parameters based on OTAR to minimizes the effort in installing the system. The detailed functions are as follows.

- Self-configuration of Initial Physical Cell ID (PCI)
- Self-configuration of initial neighbor information
- Self-configuration of initial Physical Random Access Channel (PRACH) information
- Self-configuration of initial carrier assignment
- Self-configuration of initial power

### Self-Optimization

- PCI auto-configuration
  The SON server of the LSM is responsible for allocating the initial PCI in the self-establishment procedure of a new eSmallCell, detecting a problem automatically, and selecting, changing, and setting a proper PCI when a PCI collision/confusion occurs with the neighbor cells during operation.
- Automatic Neighbor Relation (ANR) optimization
  The ANR function minimizes the network operator's effort to maintain the optimal NRT by managing the NRT dynamically depending on grow/degrow of the neighbor cells. This function automatically configures the initial NRT of each eSmallCell and recognizes environment changes, such as cell grow/degrow or new eSmallCell installation during operation to maintain the optimal NRT. In other words, the ANR function updates the NRT for each eSmallCell by automatically recognizing topology changes such as new neighbor cell or eSmallCell installation/uninstallation and adding or removing the Neighbor Relation (NR) to or from the new neighbor cell.
- Mobility robustness optimization
  The mobility robustness optimization function is the function for improving handover performance in the eSmallCell by recognizing the problem that handover is triggered at the incorrect time (e.g. too early or too late) before, after, or during handover depending on UE mobility, or handover is triggered to the incorrect target cell (handover to the wrong cell) and then by optimizing the handover parameters according to the reasons for the problem.
- Random Access Channel (RACH) optimization
  The RACH Optimization (RO) function minimizes the access delay and interference through dynamic management of the parameters related to random access.
  The RO function is divided into the initial RACH setting operation and the operation for optimizing parameters related to the RACH. The initial RACH setting operation is for setting the preamble signatures and the initial time resource considering the neighbor cells. The operation for optimizing parameters related to the RACH is for estimating the RACH resources, such as time resource and subscriber transmission power required for random access, that change depending on time, and for optimizing the related parameters.

# 4.9 Security

### Boot-loader Validation of Signed Images

The function of boot-loader validation of signed images is a function of certifying that an image distributor signs the image to inform that the distributor made and distributed the image and the user verifies the signed image to check the image was distributed by the distributer and it was not forged or modified with integrity.

- Code signing
  Creates a signature encrypting the hash value of the image to the private key held only by the distributor and distributes the image with the encrypted signature.
- Code verification
  Calculates the hash value of the image and deciphers the signature to the public key responding to the private key of the distributor. Checks that the image was not forged or modified when the deciphered value is compared with the hash value of the image and the values are same.

### No External Debug Port

Because the eSmallCell does not have the debug port exposed outside, accesses the product through the external debug port and prevents the attack of forging or modifying software.

### Anti-Tamper Detection via Light Detector

When the system cover (middle cover) is opened, it detects the light from the outside and gives an alarm that the system cover is opened. The photo sensor of the eSmallCell measures exact visible light and if the light exceeding the threshold (lux value) set by the operator is measured, the cover open alarm goes off.

- Tamper detection
  - Providing the on-chip photo sensor to measure the exact visible light from outside
  - Supporting tamper detection alarm and configurable option to enable/disable the tamper detection function via Small Cell EMS
  - Providing configurable tamper detection threshold value via Small Cell EMS
- Cover open Alarm definition/description
  - Definition: cover open alarm is defined as the eSmallCell middle cover is opened
  - Description: eSmallCell occurs cover open alarm when eSmallCell detects the visible light value is greater than the configured threshold value for 2 second period x 3 times
  - Default threshold value: 5 lux (typical side road lighting)
- Performance of detector
  - Sensitivity Range: from 1 lux to 65,000 lux
  - Reliable Light Sensing: rejection of 50 Hz/60 Hz Noise

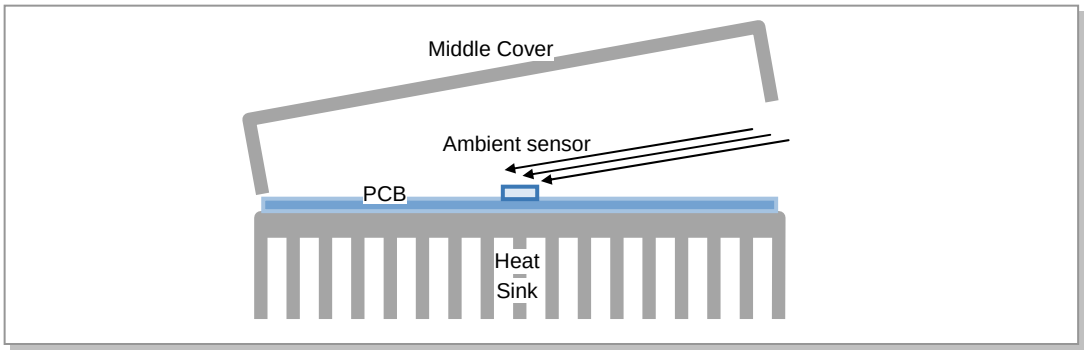



**Figure 22. Anti-Tamper Detection via Light Detector**

# 4.10 Easy Operation and Maintenance

Through interworking with the management systems (Small Cell EMS), the eSmallCell provides the maintenance functions such as system initialization and restart, system configuration management, management of fault/status/diagnosis for system resources and services, management of statistics on system resources and various performance data and security management for system access and operation.

### Graphics and Text Based Console Interfaces

The Small Cell EMS manages all eSmallCells in the network using the Database Management System (DBMS). The eSmallCell also interworks with the console terminal to allow the operator to connect directly to the Network Element (NE), rather than through the Small Cell EMS, and perform the operations and maintenance.
The operator can access the graphic based console interfaces without additional software and log in to the system using web browser such as Internet Explorer. The operator can retrieve the network configuration and system fault information.

### Operator Authentication Function

The eSmallCell provides the authentication and privilege management functions for the system operators. The operator accesses the eSmallCell using the operator’s account and password via the Web UI.

### Highly-Secured Maintenance

The eSmallCell supports the HTTP/SSL for security during communications with the Small Cell EMS, and the Secure Shell (SSH) also.

# ABBREVIATION

| | |
|---|---|
| 3GPP | 3rd Generation Partnership Project |
| 64 QAM | 64 Quadrature Amplitude Modulation |

## A

| | |
|---|---|
| AC | Admission Control |
| ADC | Analog to Digital Converter |
| AGPS | Assisted GPS |
| AKA | Authentication and Key Agreement |
| AM | Acknowledged Mode |
| AMBR | Aggregated Maximum Bit Rate |
| ANR | Automatic Neighbor Relation |
| ARQ | Automatic Repeat Request |
| AS | Access Stratum |

## B

| | |
|---|---|
| BEGEM | Beyond Enhanced GPS Engine Module |
| BGP | Border Gateway Protocol |

## C

| | |
|---|---|
| CA | Carrier Aggregation |
| C & M | Control & Maintenance |
| CC | Chase Combining |
| CFR | Crest Factor Reduction |
| CLI | Command Line Interface |
| CM | Configuration Management |
| CoS | Class of Service |
| CPLD | Complex Programmable Logic Device |
| CPS | Call Processing Software |
| CS | Circuit Service |
| CSAB | CPS SON Agent Block |
| CSM | Core System Manager |

# D

| | |
|---|---|
| DAC | Digital to Analog Converter |
| DBMS | Database Management System |
| DD | Device Driver |
| DDC | Digital Down Conversion |
| DFT | Discrete Fourier Transform |
| DHCP | Dynamic Host Configuration Protocol |
| DiffServ | Differentiated Services |
| DL | Downlink |
| DSCP | Differentiated Services Code Point |
| DSP | Digital Signal Processor |
| DUC | Digital Up Conversion |
| DUS | Debugging Utility Service |

# E

| | |
|---|---|
| ECCB | eSmallCell Call Control Block |
| ECGI | E-UTRAN Cell Global Identifier |
| ECMB | eSmallCell Common Management Block |
| ECS | eSmallCell Control processing Subsystem |
| EDS | eSmallCell Data processing Subsystem |
| EMC | Electromagnetic Compatibility |
| EMI | Electromagnetic Interference |
| EMS | Element Management System |
| eNB | evolved UTRAN Node-B |
| ENS | Event Notification Service |
| E/O | Electric-to-Optic |
| EPC | Evolved Packet Core |
| EPS | Evolved Packet System |
| ES | Energy Saving |
| ESM | Energy Saving Management |
| ESM | EPC System Manager |
| E-UTRAN | Evolved UTRAN |

# F

| | |
|---|---|
| FDD | Frequency Division Duplex |
| FE | Fast Ethernet |
| FHS | File-system Hierarchy Standard 2.2 |
| FM | Fault Management |
| FSTD | Frequency Switched Transmit Diversity |
| FTP | File Transfer Protocol |

# G

| | |
|---|---|
| GBR | Guaranteed Bit Rate |
| GE | Gigabit Ethernet |
| GPRS | General Packet Radio Service |
| GPS | Global Positioning System |
| GTP | GPRS Tunneling Protocol |
| GTPB | GPRS Tunneling Protocol Block |
| GTP-U | GTP-User |
| GW | Gateway |

# H

| | |
|---|---|
| HARQ | Hybrid Automatic Repeat Request |
| HAS | High Availability Service |
| HO | Handover |
| HSS | Home Subscriber Server |
| HTTP | Hyper Text Transfer Protocol |
| HTTPs | Hyper Text Transfer Protocol over SSL |

# I

| | |
|---|---|
| ICIC | Inter-Cell Interference Coordination |
| ICMP | Internet Control Message Protocol |
| IDFT | Inverse Discrete Fourier Transform |
| IETF | Internet Engineering Task Force |
| IF | Intermediate Frequency |
| IP | Internet Protocol |
| IPRS | IP Routing Software |
| IPSS | IP Security Software |
| IPv4 | Internet Protocol version 4 |
| IPv6 | Internet Protocol version 6 |
| IR | Incremental Redundancy |

# L

| | |
|---|---|
| L7IA | LTE 7 baseband and transceiver Integrated board Assembly |
| LMT | Local Maintenance Tool |
| LNA | Low Noise Amplifier |
| LSM | LTE System Manager |
| LTE | Long Term Evolution |

# M

| | |
|---|---|
| MAC | Medium Access Control |
| MACB | Medium Access Control Block |
| MBR | Maximum Bit Rate |
| MCS | Modulation Coding Scheme |
| MDS | Message Delivery Service |
| MFS | Miscellaneous Function Service |
| MIB | Master Information Block |
| MIMO | Multiple-Input Multiple-Output |
| MMC | Man Machine Command |
| MME | Mobility Management Entity |
| MSS | Master SON Server |
| MTAS | Multimedia Telephony Application Server |
| MU | Multiuser |

# N

| | |
|---|---|
| NAS | Non-Access Stratum |
| NE | Network Element |
| NP | Network Processing |
| NPC | Network Processing Control |
| NR | Neighbor Relation |
| NRT | Neighbor Relation Table |

# O

| | |
|---|---|
| OAM | Operation and Maintenance |
| OCNS | Orthogonal Channel Noise Simulator |
| OCS | Online Charging System |
| O/E | Optic-to-Electric |
| OFCS | Offline Charging System |
| OFD | Optic Fiber Distributor |
| OFDMA | Orthogonal Frequency Division Multiple Access |
| OMA-DMOTA | Open Mobile Alliance-Device Management Over The Air |
| OS | Operating System |
| OSAB | OAM SON Agent Block |
| OSPF | Open Shortest Path First |
| OSS | Operating Support System |
| OTAR | Over the air Receiver |

# P

| | |
|---|---|
| PAPR | Peak-to-Average Power Ratio |
| PCI | Physical Cell Identity |
| PCRF | Policy and Charging Rule Function |
| PD | Power Detector |
| PDCB | PDCP Block |
| PDCP | Packet Data Convergence Protocol |
| PDN | Packet Data Network |
| PDU | Protocol Data Unit |
| P-GW | PDN Gateway |
| PLER | Packet Loss Error Rate |
| PM | Performance Management |
| PMI | Precoding Matrix Indicator |
| PMIP | Proxy Mobile IP |
| PoE | Power over Ethernet |
| PRACH | Physical Random Access Channel |
| PRB | Physical Resource Block |
| PSE | Power Source Equipment |
| PSS | Primary Synchronization Signal |
| PTP | Precision Time Protocol |

# Q

| | |
|---|---|
| QCI | QoS Class Identifier |
| QoS | Quality of Service |
| QPSK | Quadrature Phase Shift Keying |

# R

| | |
|---|---|
| RACH | Random Access Channel |
| RB | Radio Bearer |
| RB | Resource Block |
| RET | Remote Electrical Tilt |
| RF | Radio Frequency |
| RFS | Root File System |
| RLC | Radio Link Control |
| RLCB | Radio Link Control Block |
| RO | RACH Optimization |

# S

| | |
|---|---|
| S1-AP | S1 Application Protocol |
| SC | Single Carrier |
| SC-FDMA | Single Carrier Frequency Division Multiple Access |
| SCTB | SCTP Block |
| SCTP | Stream Control Transmission Protocol |
| SDU | Service Data Unit |
| SFBC | Space Frequency Block Coding |
| SFN | System Frame Number |
| SFTP | SSH File Transfer Protocol |
| S-GW | Serving Gateway |
| SIBs | System Information Blocks |
| SM | Spatial Multiplexing |
| SMC | Security Mode Command |
| SMS | Short Message Service |
| SNMP | Simple Network Management Protocol |
| SON | Self Organizing Network |
| SSH | Secure Shell |
| SSS | Secondary Synchronization Signal |
| STBC | Space Time Block Coding |
| SU | Single User |
| SwM | Software Management |

# T

| | |
|---|---|
| TA | Tracking Area |
| THS | Task Handling Service |
| TM | Test Management |
| TOD | Time Of Day |
| TrM | Trace Management |

# U

| | |
|---|---|
| UDA | User Defined Alarm |
| UDE | User Defined Ethernet |
| UDP | User Datagram Protocol |
| UE | User Equipment |
| UL | Uplink |
| UTRAN | UMTS Terrestrial Radio Access Network |

# V

| | |
|---|---|
| VLAN | Virtual Local Area Network |
| VSWR | Voltage Standing Wave Ratio |

LTE eSmallCell

# System Description

## FCC Information

This device complies with part 15 of the FCC Results. Operation is subject to the following two conditions :

(1) This Device may not cause harmful interface, and

(2) This device must accept any interference received, including interference that may cause undesired operation.

Note: This equipment has been tested and found to comply with the limits for CLASS B digital device, pursuant to Part 15 of FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try correct the interference by one or more of the following measures:

1.1. Reorient or relocate the receiving antenna.
1.2. Increase the separation between the equipment and receiver.
1.3. Connect the equipment into an outlet on a circuit different from that to which receiver is connected.
1.4. Consult the dealer or experienced radio/TV technician for help.

## WARNING

Changes or modifications not expressly approved by the manufacturer could void the user's authority to operate the equipment.

"CAUTION : Exposure to Radio Frequency Radiation.
Antenna shall be mounted in such a manner to minimize the potential for human contact during normal operation. The antenna should not be contacted during operation to avoid the possibility of exceeding the FCC radio frequency exposure limit.